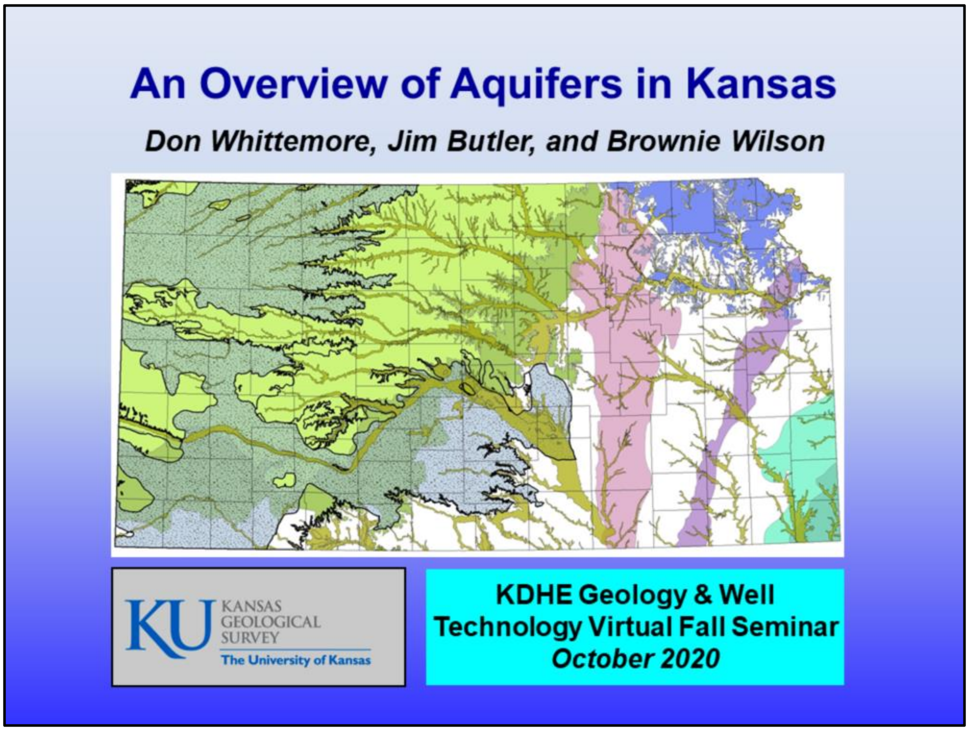
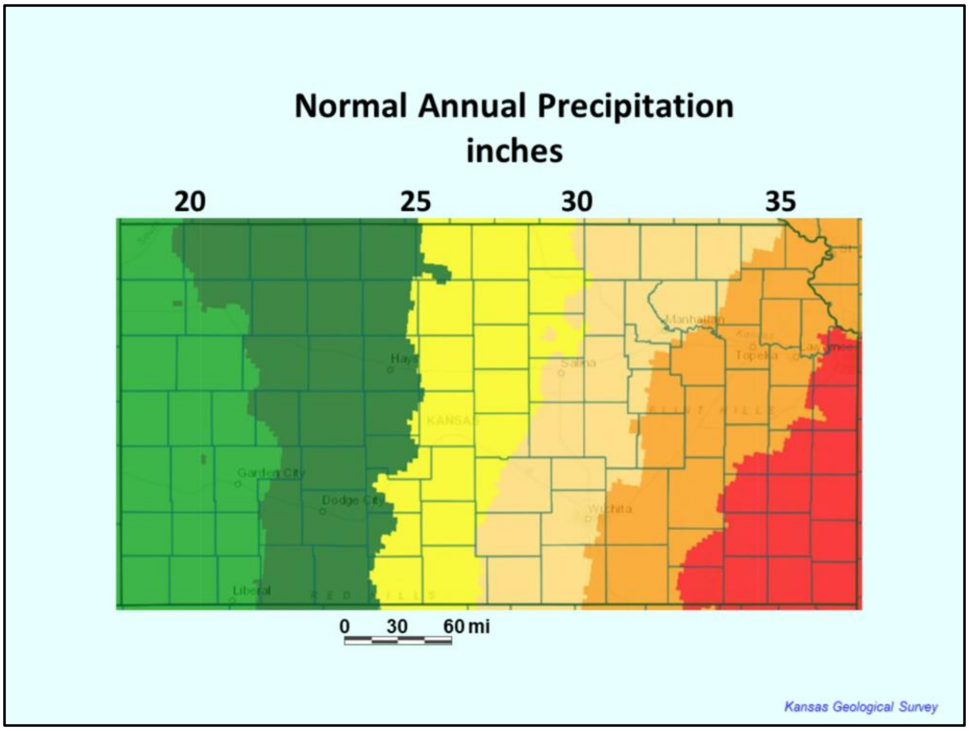
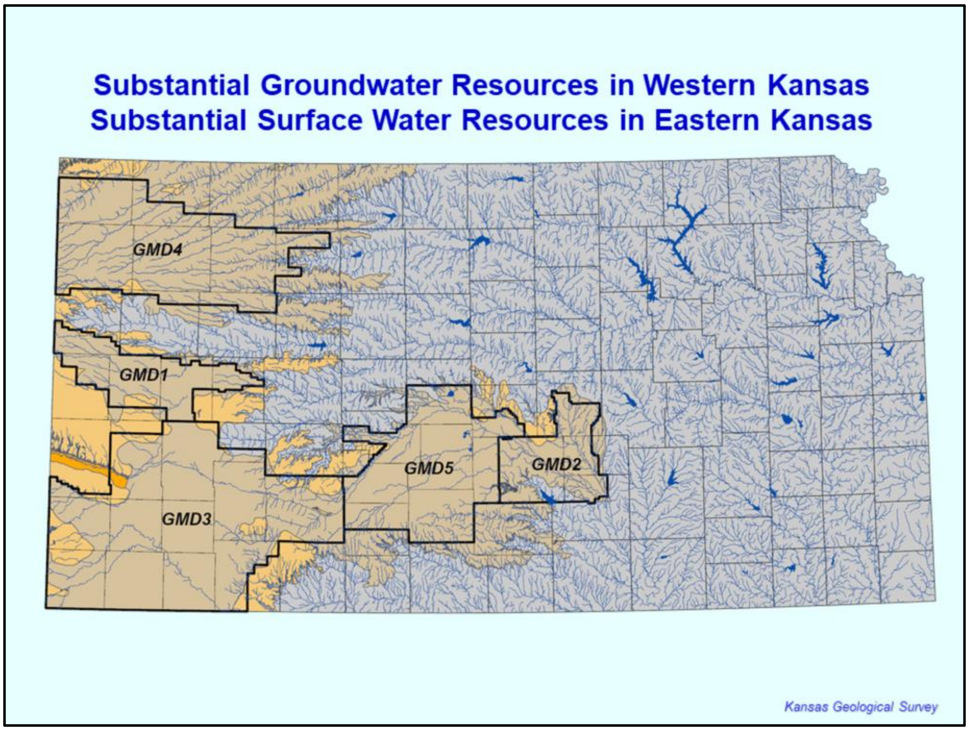


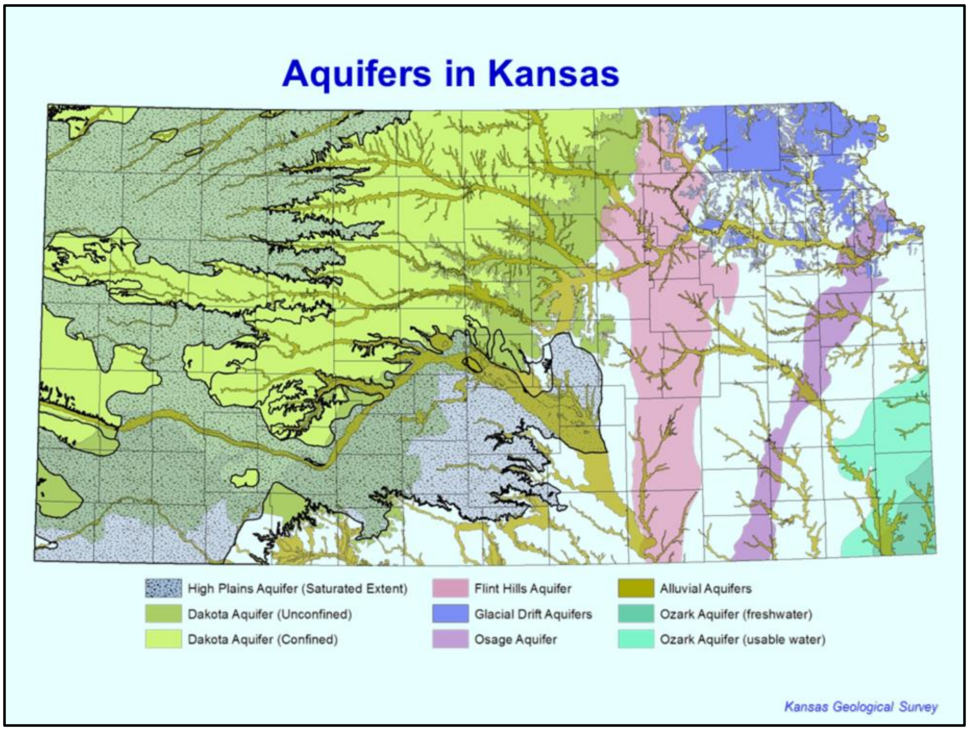
Welcome to this overview of aquifers in Kansas. I am Don Whittemore and my co-authors are Jim Butler and Brownie Wilson, also at the Kansas Geological Survey at the University of Kansas.



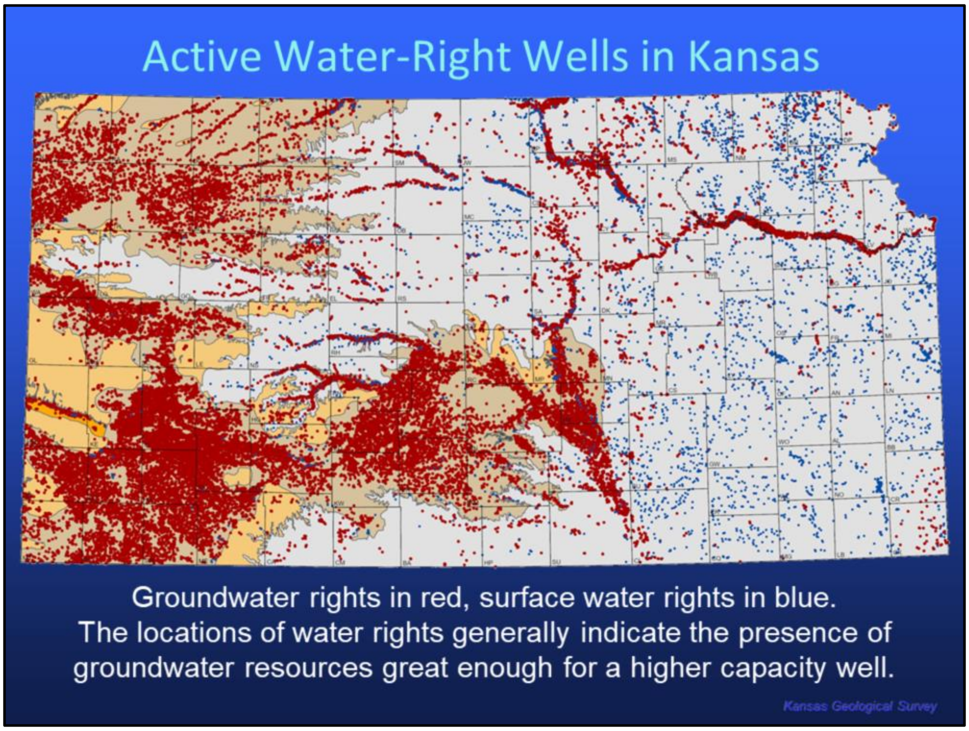
An important factor in the distribution and use of water in Kansas is the normal annual precipitation, which is substantial in the easternmost part of the state and low in the western areas. Thus, surface water sources are appreciably greater in eastern than in western Kansas.



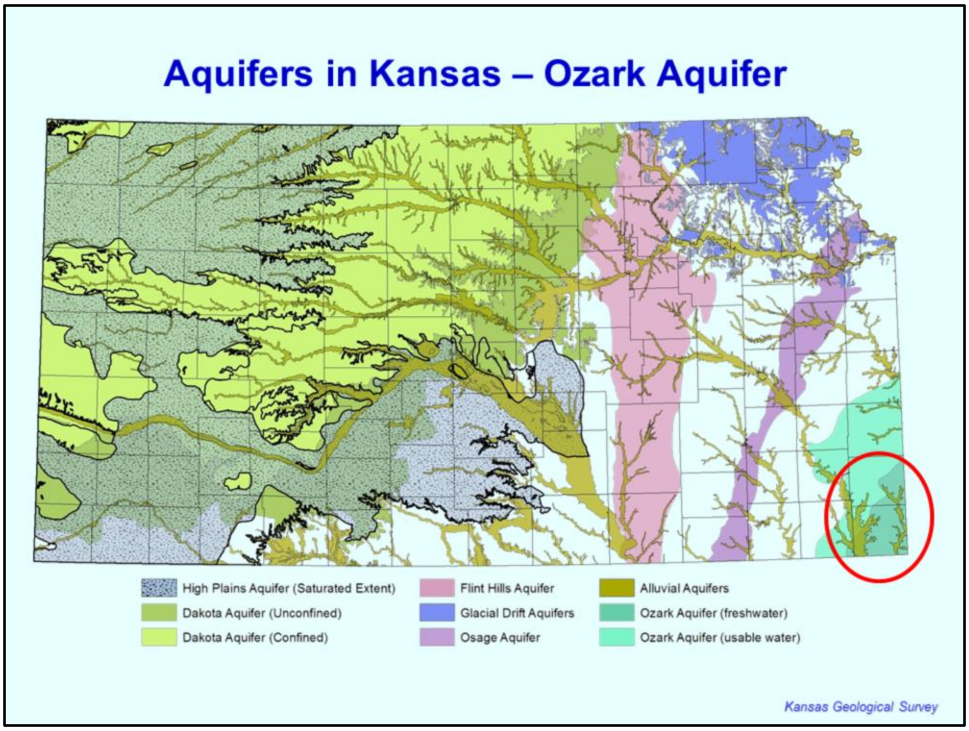
Fortunately, the most productive aquifer in Kansas, the High Plains aquifer shown here in the tan color, is in the west where it is dry and surface water sources are scarce.



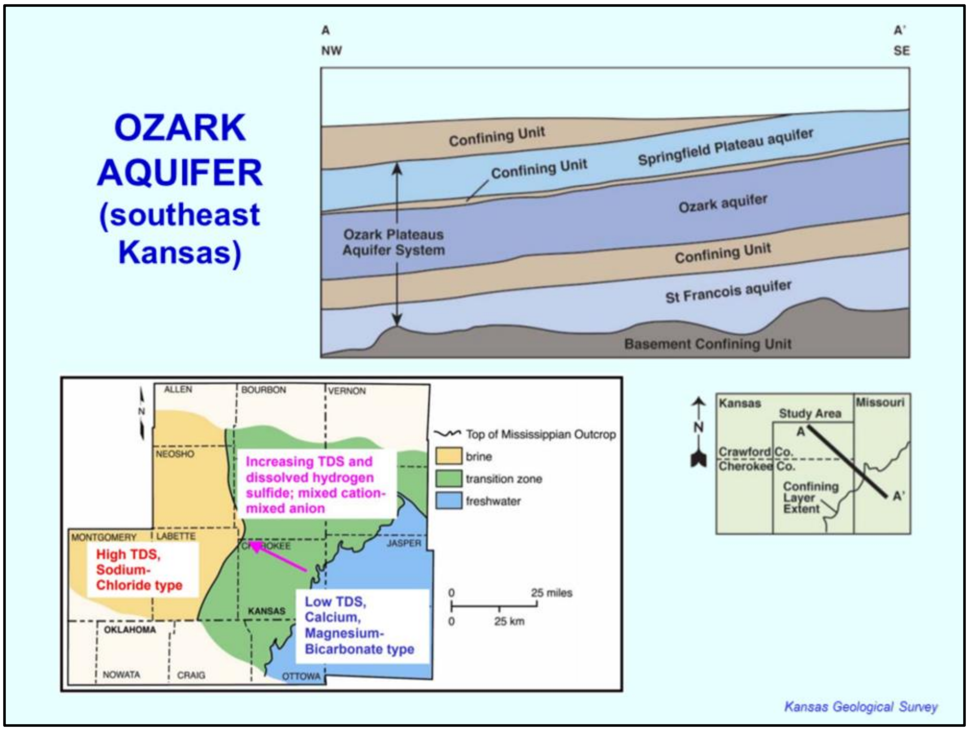
Seven different regional aquifers exist in Kansas. Bedrock aquifers include the deep Ozark aquifer in the southeast corner of the state, the Osage aquifer along this purple band in eastern Kansas, the Flint Hills aquifer along the north-south pink band, and the Dakota aquifer that lies at the surface or underlies other rocks or sediments in much of the western two-thirds of the state. Aquifers composed of unconsolidated sediments include the High Plains aquifer in the western half of Kansas, alluvial aquifers along river valleys, and the glacial drift aquifer in blue in the northeast. I will discuss features of these aquifers.



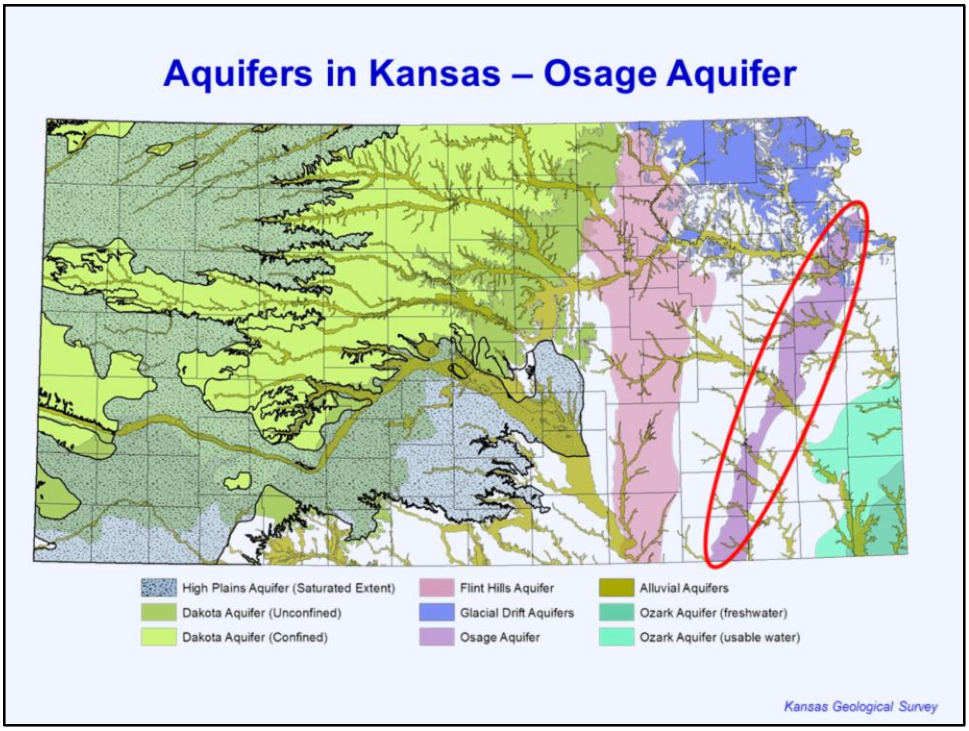
Kansas requires that water sources providing or affecting over a certain volume of water obtain a permit. This map displays the active groundwater rights as red dots and the active surface water rights as blue dots. The distribution of the groundwater rights provides a good indication of where the most important aquifers are located in the state; they outline well where the most prolific areas of the High Plains aquifer occur across the western and south-central regions, and the best alluvial aquifers as indicated by the red strips along selected river valleys.



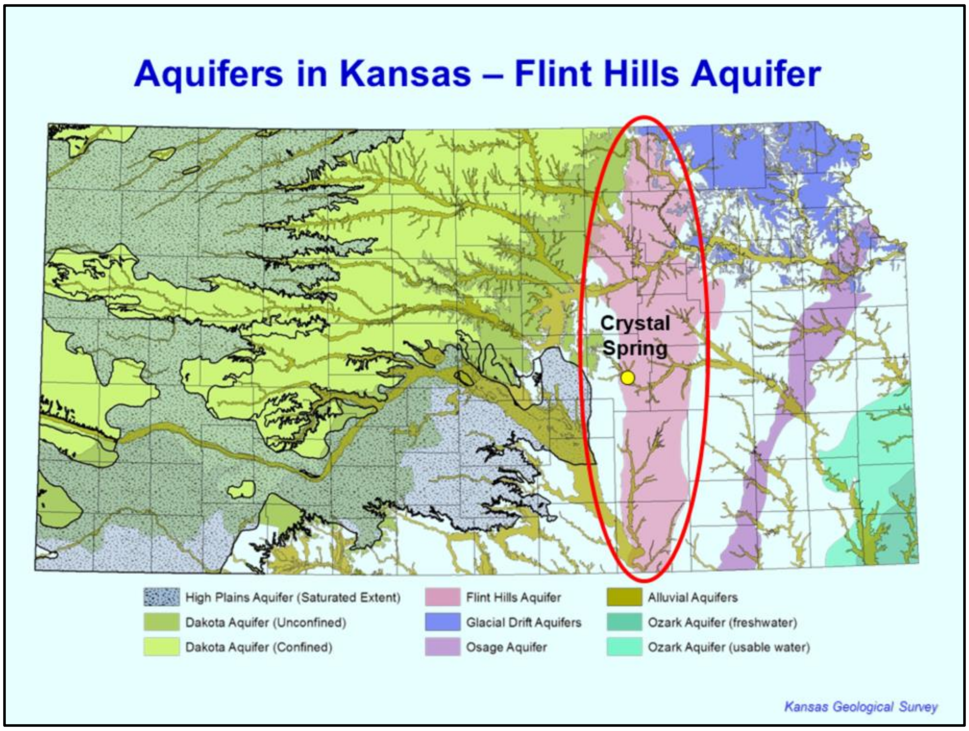
The Ozark aquifer, also known as the Cambro-Ordovician aquifer, or Arbuckle or Roubidoux aquifer, occurs in the southeast corner of Kansas. Wells obtain water from carbonate rocks at a depth of from a few hundred to over a thousand feet. Freshwater primarily exists in Cherokee and Crawford counties, the deeper blue green color; the water becomes saline to the north and the west, the lighter blue-green color.



A cross section from northwest to southeast from Crawford County into southwest Missouri shows the dip of the rocks to the northwest. Much of the aquifer in Kansas is confined by overlying rocks. Recharge to the aquifer is from the east in Missouri. As the Cambro-Ordovician rocks become deeper, less of the original saltwater in the confined rocks has been flushed out. Going from Missouri into Kansas, the water quality changes from low total dissolved solids, the blue color, to increasing dissolved solids in which chloride is high, the green color, to sodium-chloride saltwater, the yellow color. Oil is produced from the same Cambro-Ordovician units in the yellow colored area that is to the west of the usable aquifer.



The Osage aquifer extends as a band in eastern Kansas where Pennsylvanian sandstones and limestones outcrop. The aquifer does not provide substantial amounts of water except for a few areas where thick enough sandstones with freshwater occur. Several small municipalities obtain water supplies from the Tonganoxie and Ireland sandstones in the northern half of the aquifer, for example, the cities of Tonganoxie and Baldwin.

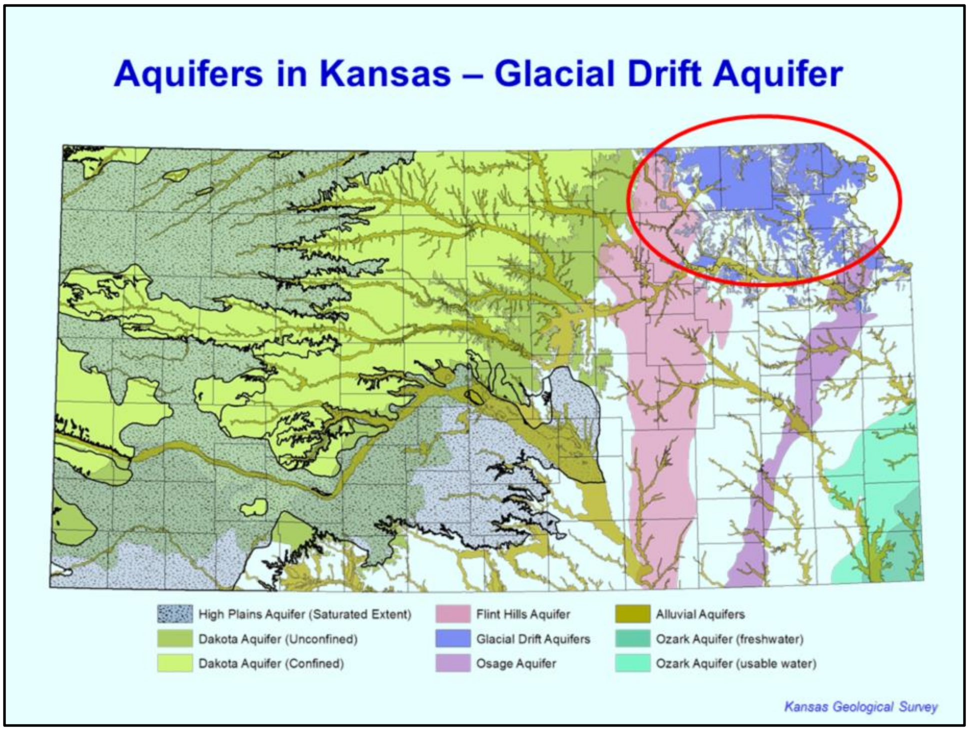


The Flint Hills aquifer is located in a north-south band where primarily Permian rocks outcrop. Wells obtain water mainly from fractured carbonate rocks in which some of the fractures have been widened by dissolution of the limestones. Most wells in the aquifer produce only small amounts of water for domestic and stock uses. However, Crystal Spring that emanates from the aquifer in Marion County provides enough water to supply the municipal needs of the small city of Florence.

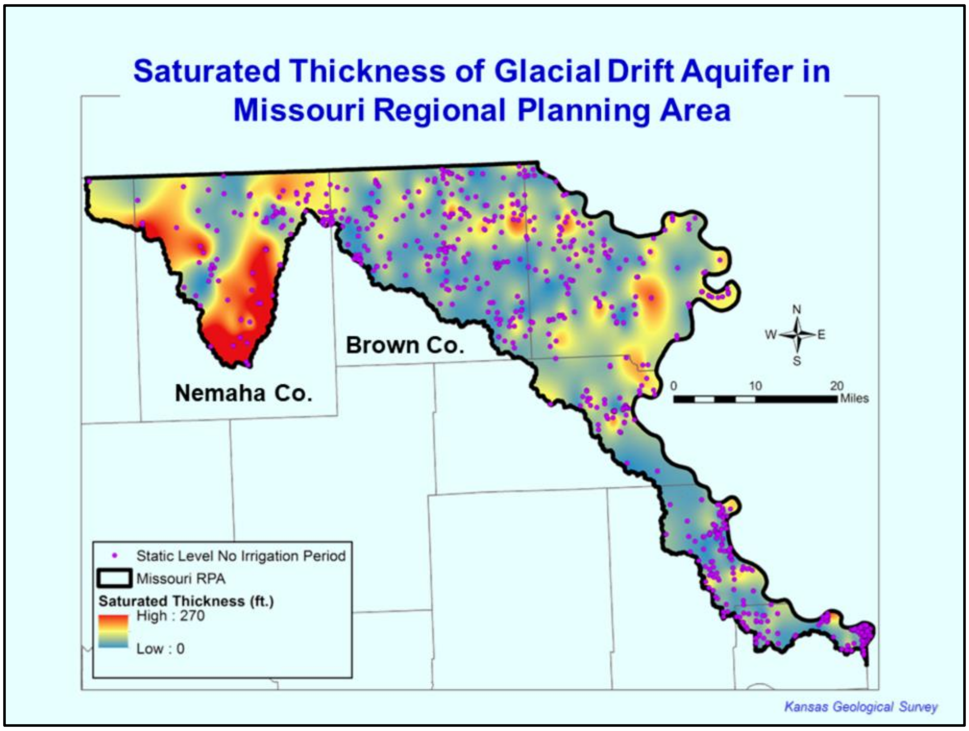
Crystal Spring
Public Water Supply for Florence, Marion County

From website "Find a Spring", https://findaspring.com/
Crystal Spring, Florence, KS

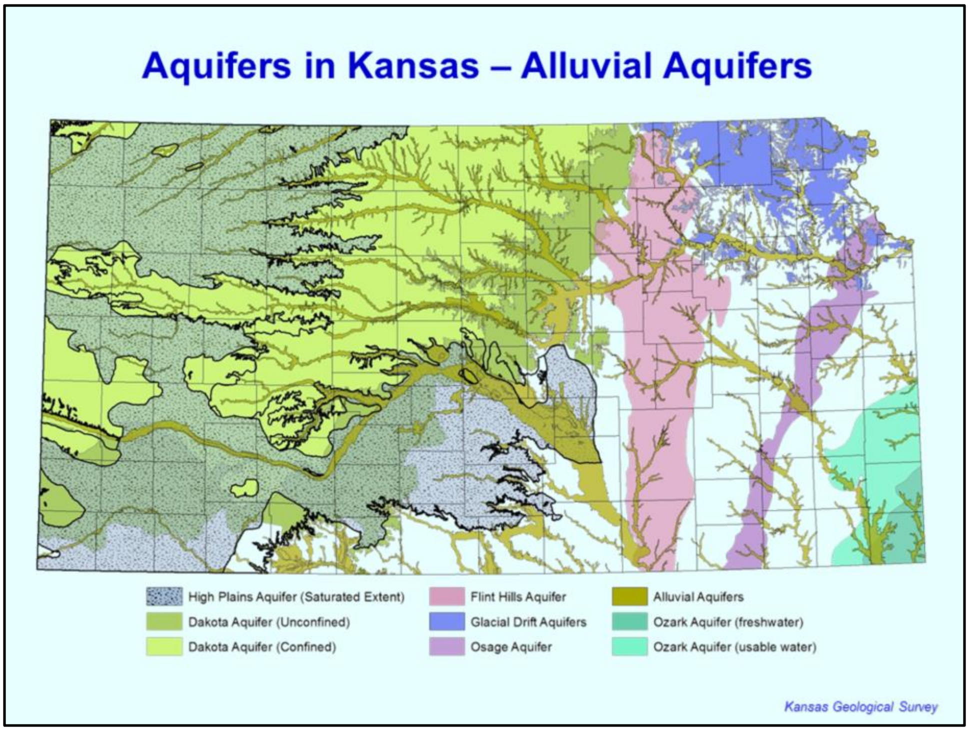
Florence taps the spring at its source; the left-hand picture indicates that the spring flow is large enough to generate a creek below the spring, and the right-hand photo shows the water plant of Florence at the spring.



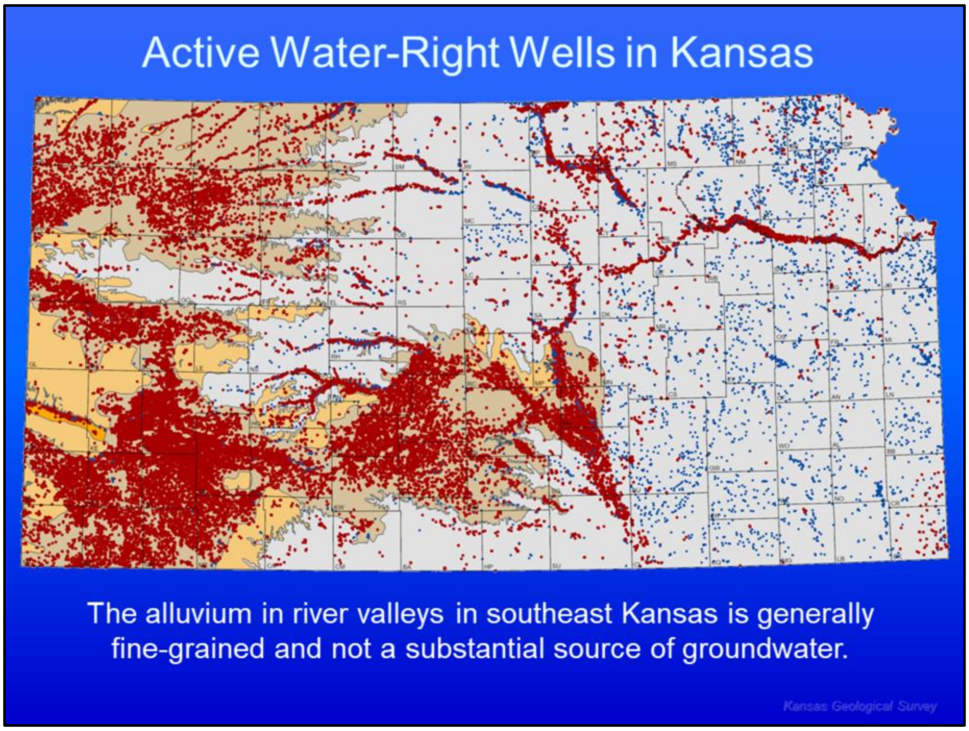
The glacial drift aquifer occurs in northeast Kansas where sands and gravels are distributed within and underlying glacial drift deposits. The best portions of the aquifer are portions of buried river valleys.



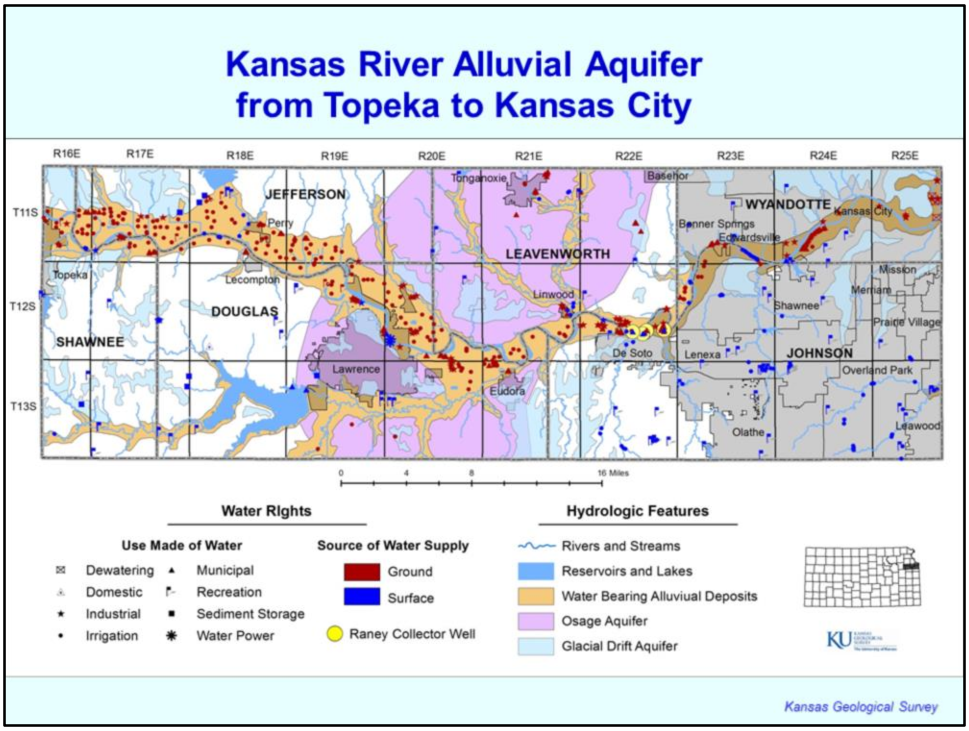
The distribution of the glacial drift aquifer is very heterogeneous as indicated by this map of the saturated thickness within the Missouri River regional planning area of Kansas. The locations of the thicker saturated thickness in this area, such as in Nemaha County, do not necessarily indicate the most productive aquifer because much of the sediments are fine grained. For example, wells in parts of Brown County produce enough water for irrigation.



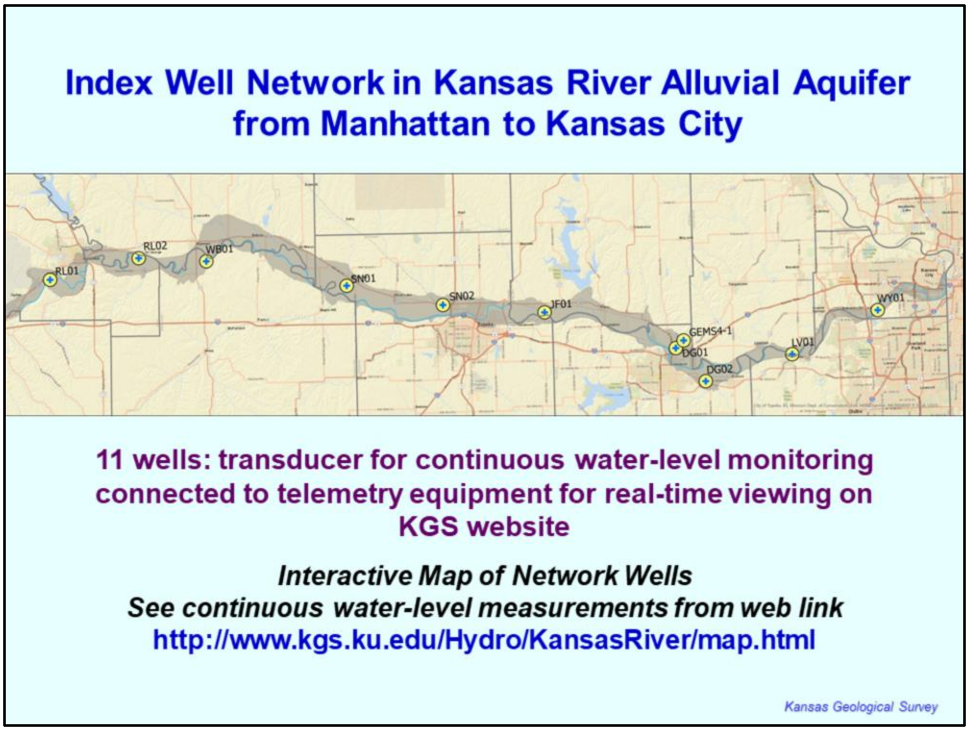
Alluvial aquifers are distributed across the state, as indicated by the olive green color that follows river and stream valleys.



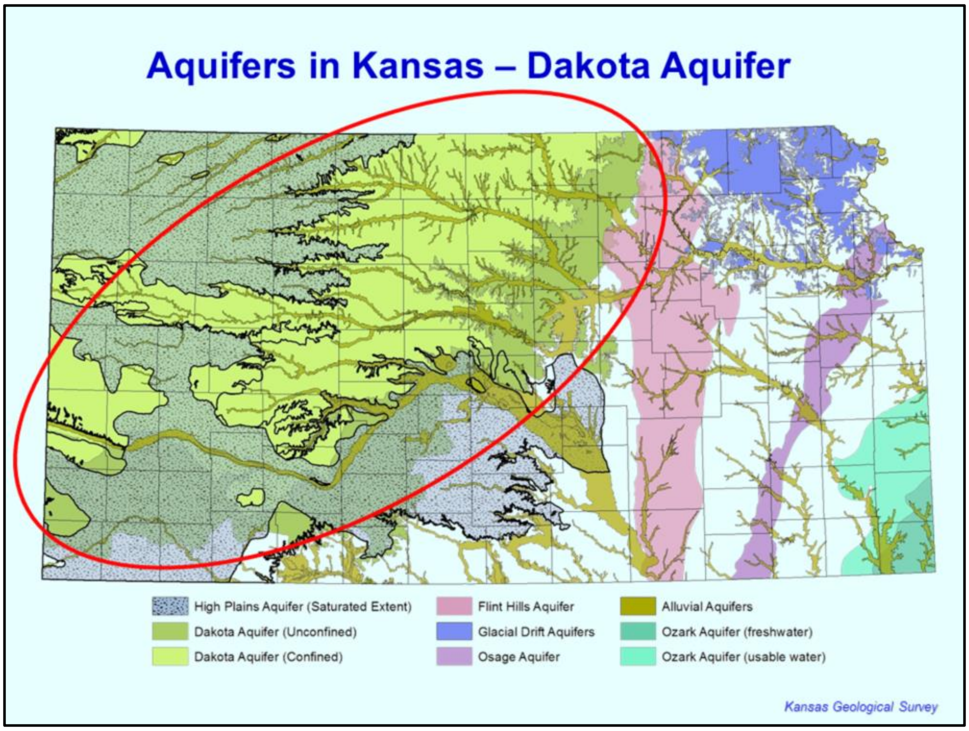
The most prolific alluvial aquifers, as indicated by the red points for groundwater rights along the river and stream valleys, are located in the northeast, north-central, and south-central areas of Kansas. The alluvium in river valleys in southeast Kansas is generally fine-grained and not a substantial source of groundwater.



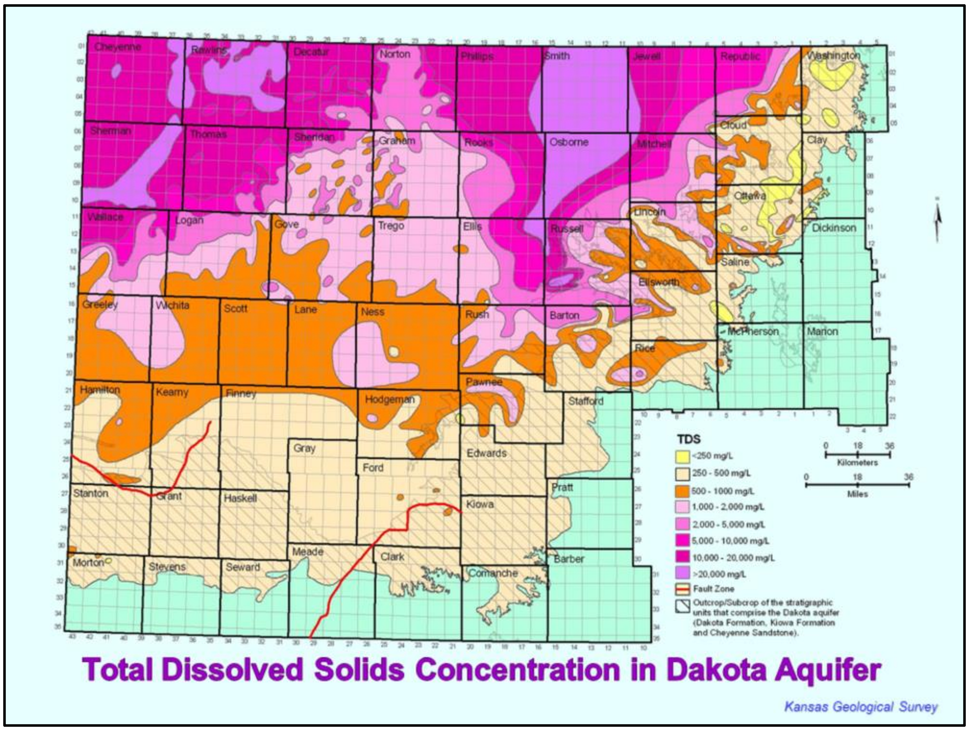
Substantial amounts of water are pumped from the Kansas River alluvial aquifer. This map displays groundwater rights in a portion of northeast Kansas from Topeka to Kansas City. Most of the red dots in the western portion of this map represent irrigation wells. In the eastern part of the map large quantities of water are pumped from municipal and industrial wells along the Kansas River valley.



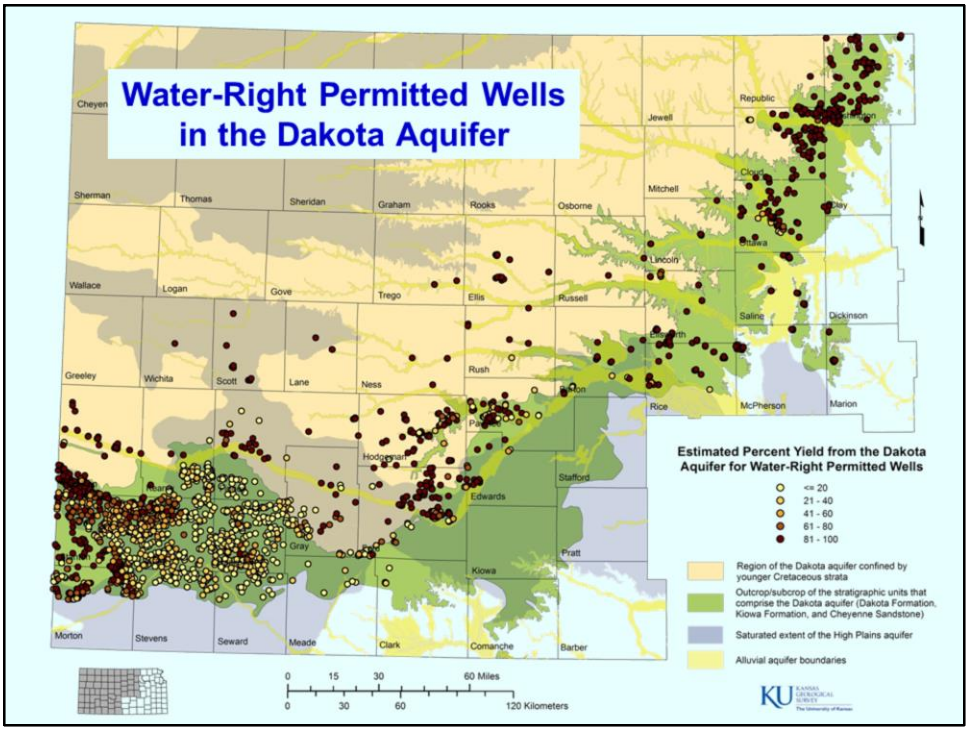
The Kansas Geological Survey has established an index well network in the alluvial aquifer from Manhattan to Kansas City to provide data to better understand the relationship of groundwater levels to Kansas River levels. The data will eventually be used for a groundwater model incorporating groundwater and surface water interactions that can aid planning and management of the water resources in the river valley. The network currently comprises 11 wells with transducers that continuously record groundwater levels and that are connected to telemetry equipment for real-time viewing on the KGS website. The web link for those measurements is provided here.



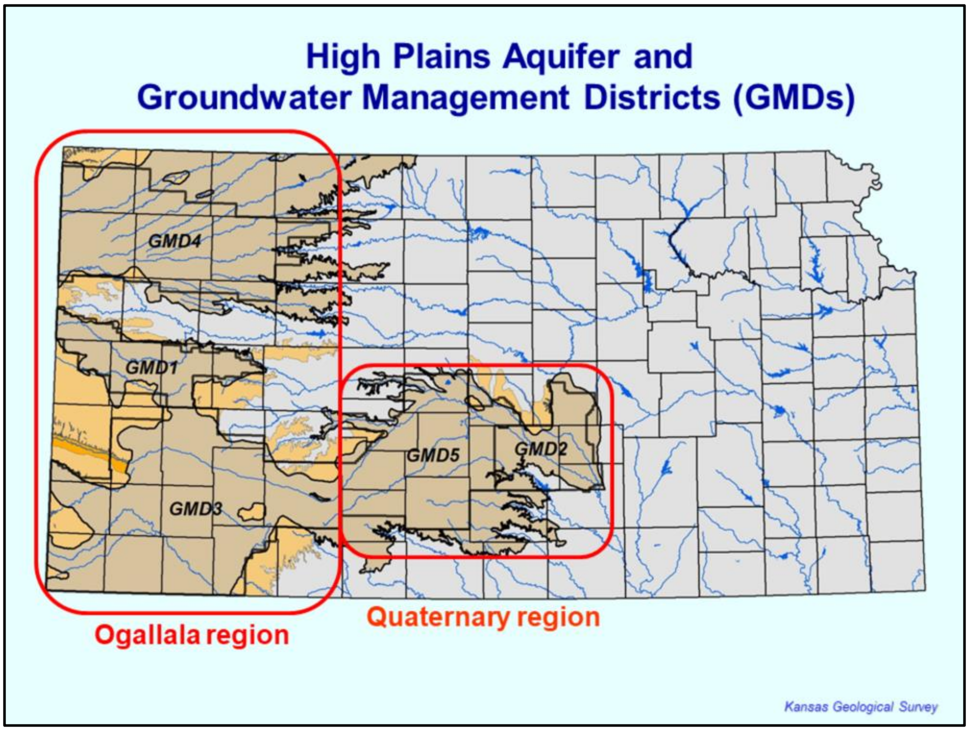
The Dakota aquifer covers a substantial part of north-central and western Kansas. The aquifer consists of sandstone units interlayered in shale and siltstone. The aquifer outcrops in north-central Kansas (the green area), underlies the High Plains aquifer in the southern part of southwest Kansas, and is confined by overlying rocks in most of the rest of its extent (the light yellow-green area as well as much of the High Plains aquifer area).



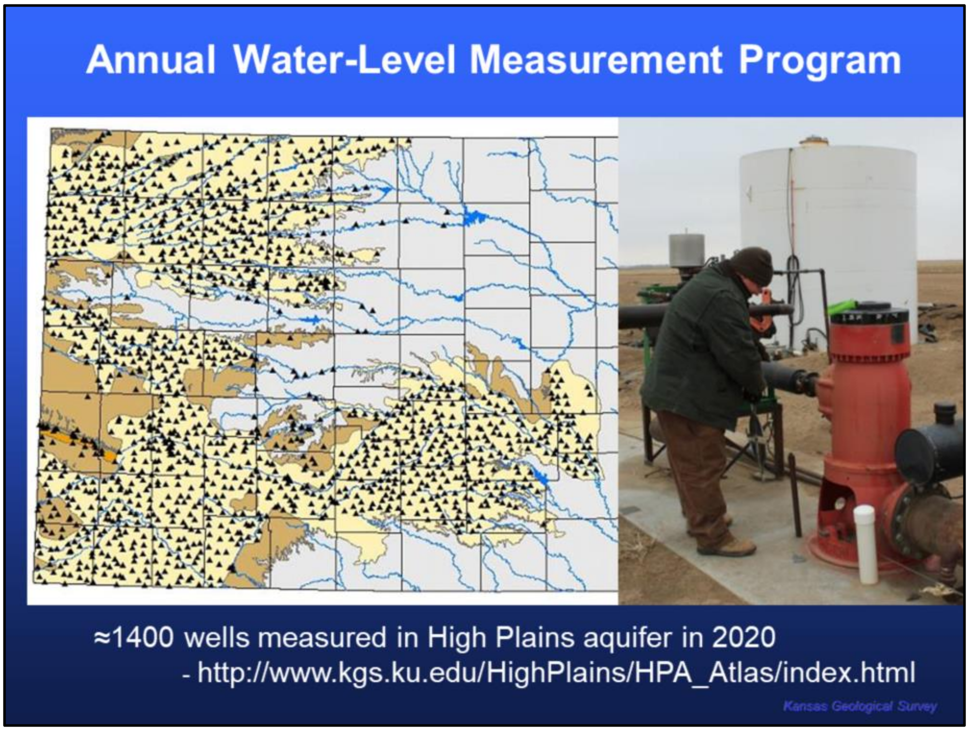
Although the Dakota aquifer extends over a wide area of Kansas, only part of that area contains freshwater. This map indicates the freshwater areas, those with less than 1000 mg/L total dissolved solids, in the yellow, tan, and orange colors. The rest of the aquifer contains saline water to saltwater that is primarily of sodium-chloride type, the pink to purple colored areas.



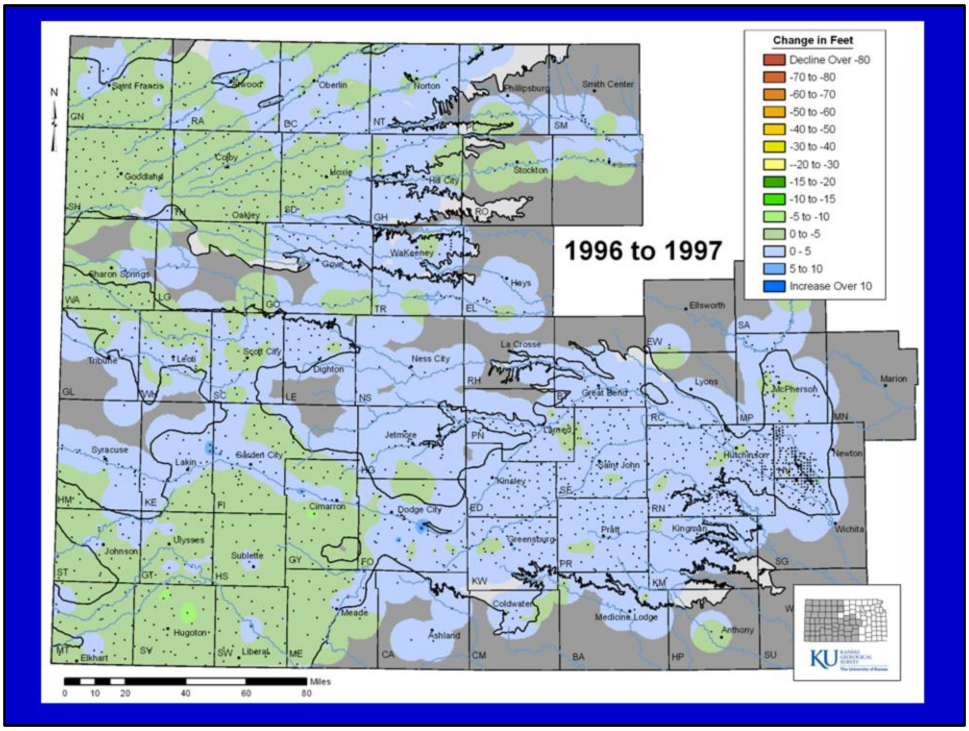
Although most wells drilled into the Dakota aquifer obtain their water from only Dakota units, many of the wells in southwest Kansas that are screened in the High Plains aquifer extend down into and produce some water from the Dakota aquifer. Those wells are represented by the lighter colored circles, indicating from less than half to less than 20% of the total water produced as derived from the Dakota aquifer.



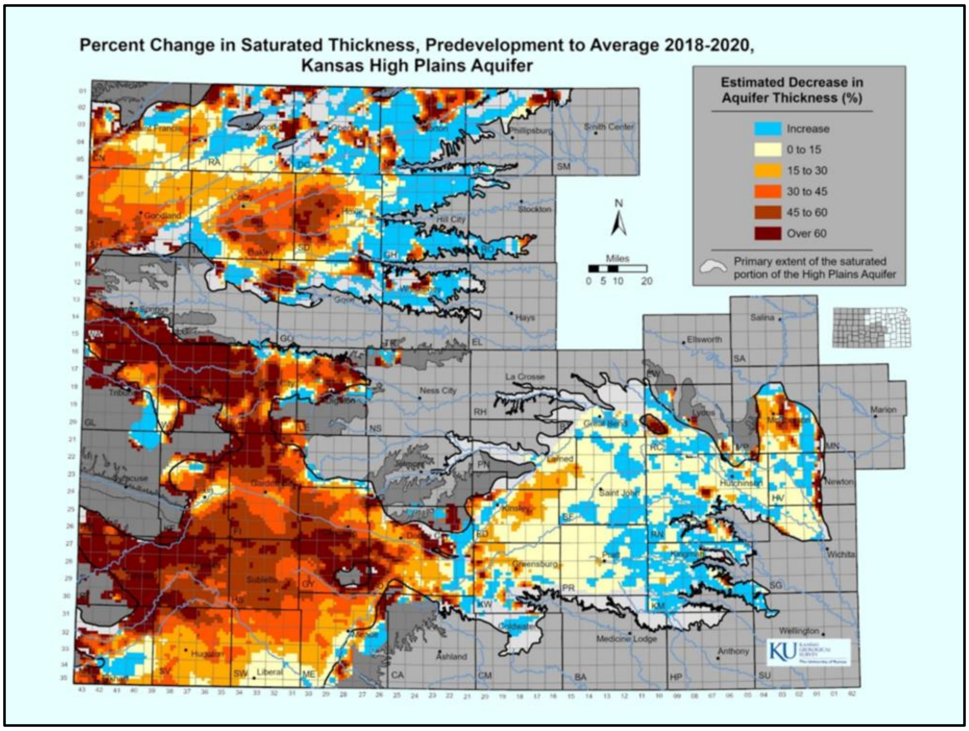
By far the most important aquifer in Kansas is the High Plains aquifer. It includes two regions, the Ogallala aquifer in the west and the Quaternary region in south-central Kansas. Five groundwater management districts, represented by GMD on this map, cover the aquifer.



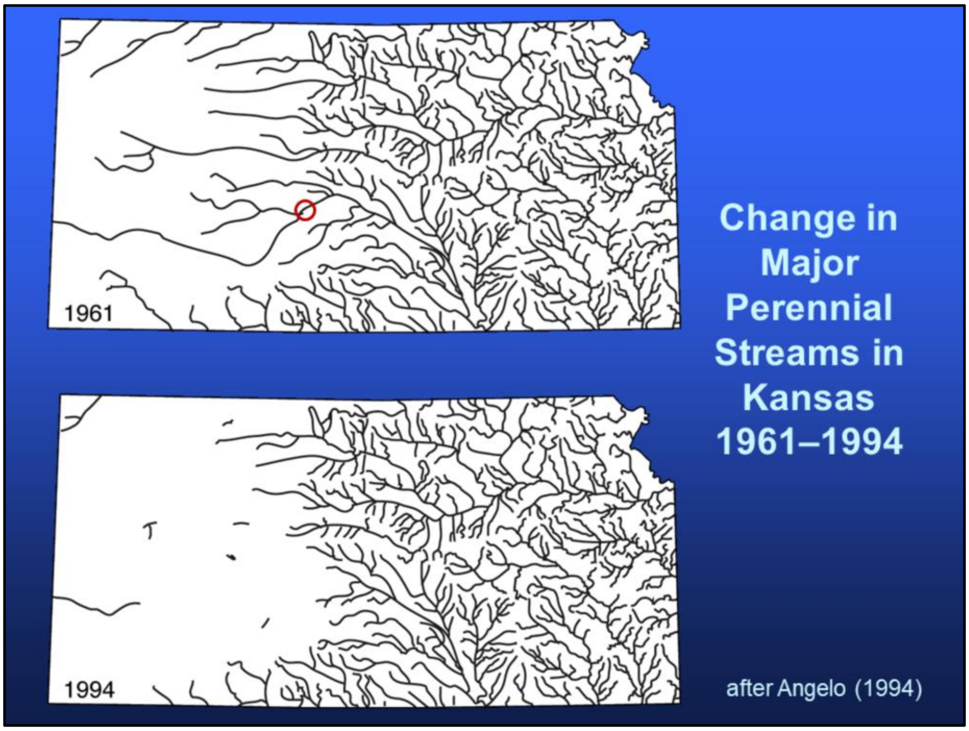
The Kansas Geological Survey and the Division of Water Resources in the Kansas Department of Agriculture measure water levels each winter in about 1400 wells across the aquifer. These data are valuable for assessing the status and changes in the aquifer.



This animation shows the change in water levels from 1996 to 2019 in the High Plains aquifer. The green to yellow to red-orange colors indicate increasing declines in the aquifer water levels. Blue colors represent water-level rises. The declines are greatest in southwest Kansas as well as parts of northwest and west-central Kansas. Declines in the red-orange color are greater than 80 ft. Water levels have not changed much in the wetter region of south-central Kansas, expect in a western portion of the area.

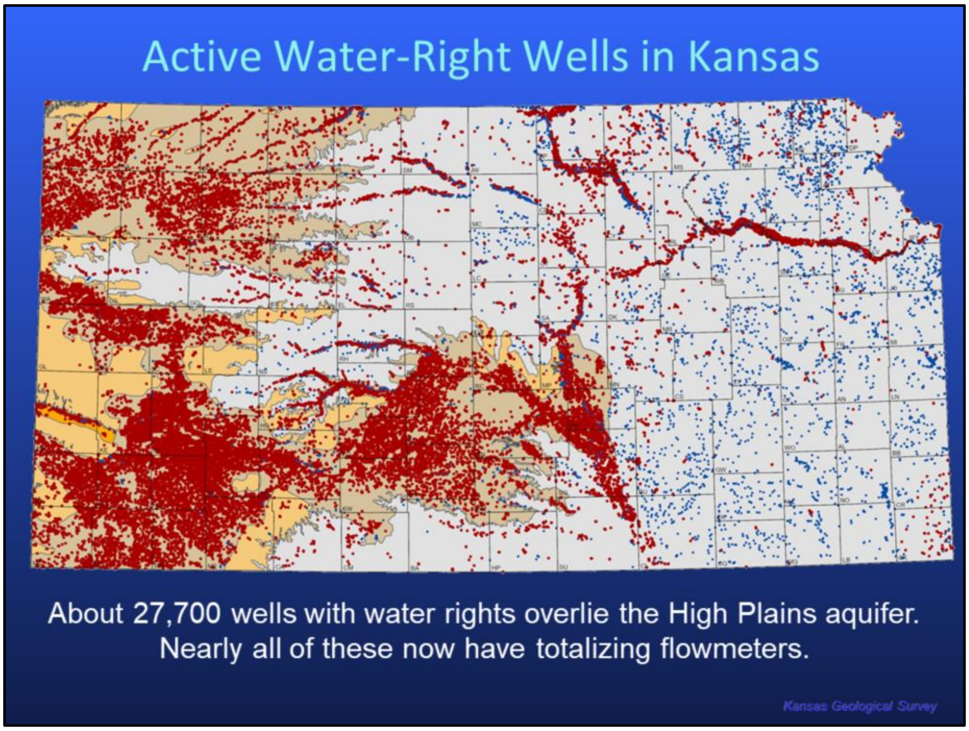


The water-level declines have caused the saturated thickness of the High Plains aquifer to decrease by over 60% in parts of the Ogallala region, as shown by the brown color. These large declines cover most of west-central Kansas where GMD No. 1 is located, as well as parts of GMDs 4 and 3. The saturated thickness of the aquifer is thin in the blue areas of western Kansas and the pumping is much less than in the areas with thickness decreases.

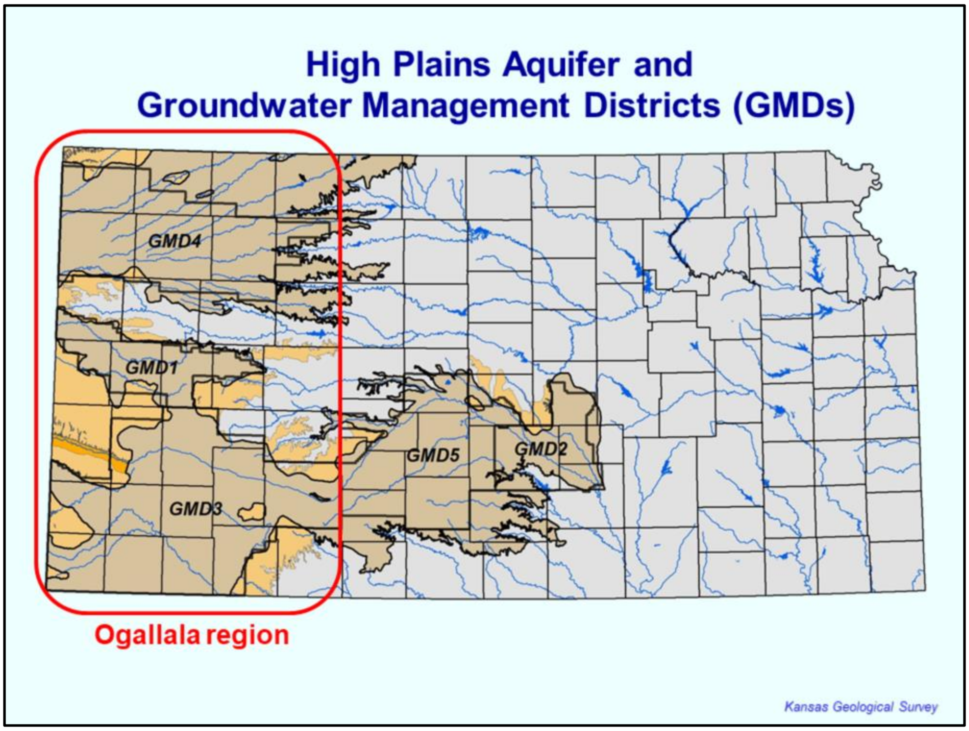


Declines in groundwater levels underlying streams across the High Plains aquifer cause a decrease in groundwater discharge to the streams until finally no discharge occurs and the streams go dry. Bob Angelo of KDHE illustrated the change by showing perennial stream channels in 1961 and 1994. Included in the disappearing streams is the Arkansas River channel, which extended across the state in 1961 but now no longer flows for over 100 to about 200 miles depending on the precipitation for a particular year. For example, the Arkansas River downstream of Larned is represented by the red circle on the 1961 map.

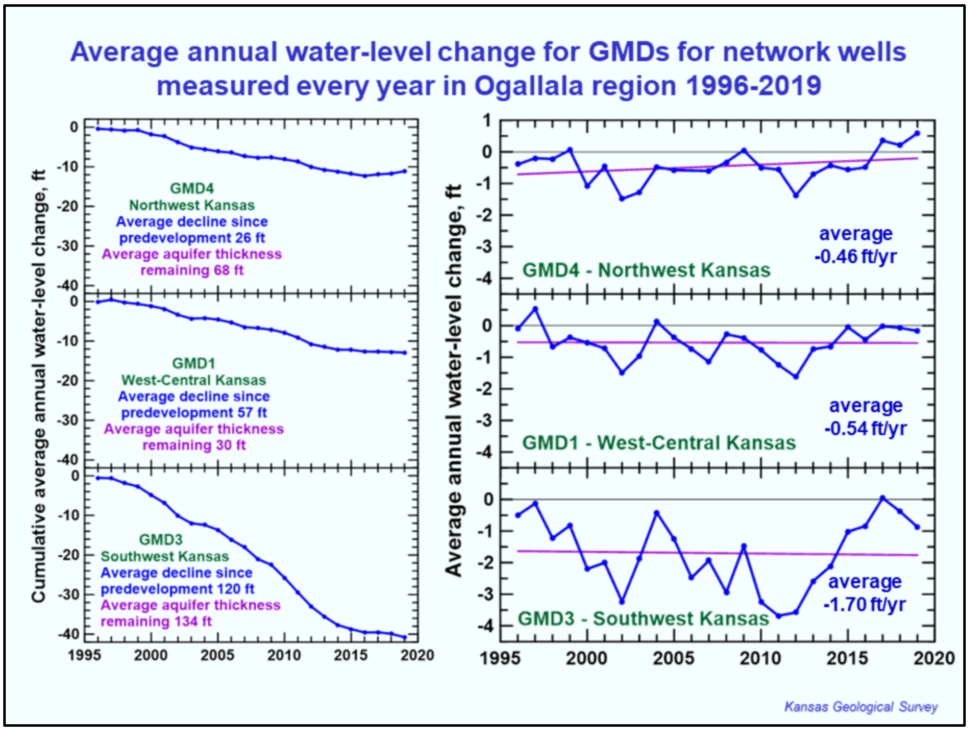
Much of the last three decades the channel of the Arkansas River near Larned is dry as shown in this photo. People often navigate down the river here in their ATVs.



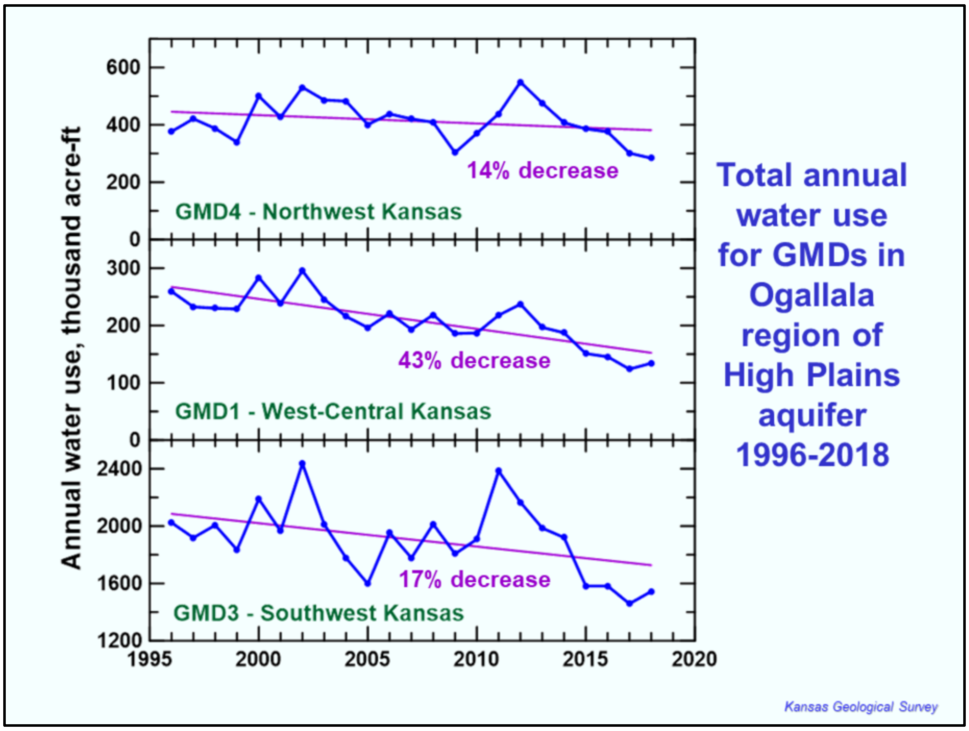
The locations of active water right wells illustrate the location of the productive parts of the High Plains aquifer. About 27,700 wells have water rights and nearly all of these wells now have totalizing flow meters. The result is that Kansas has the best groundwater use data of the nation.



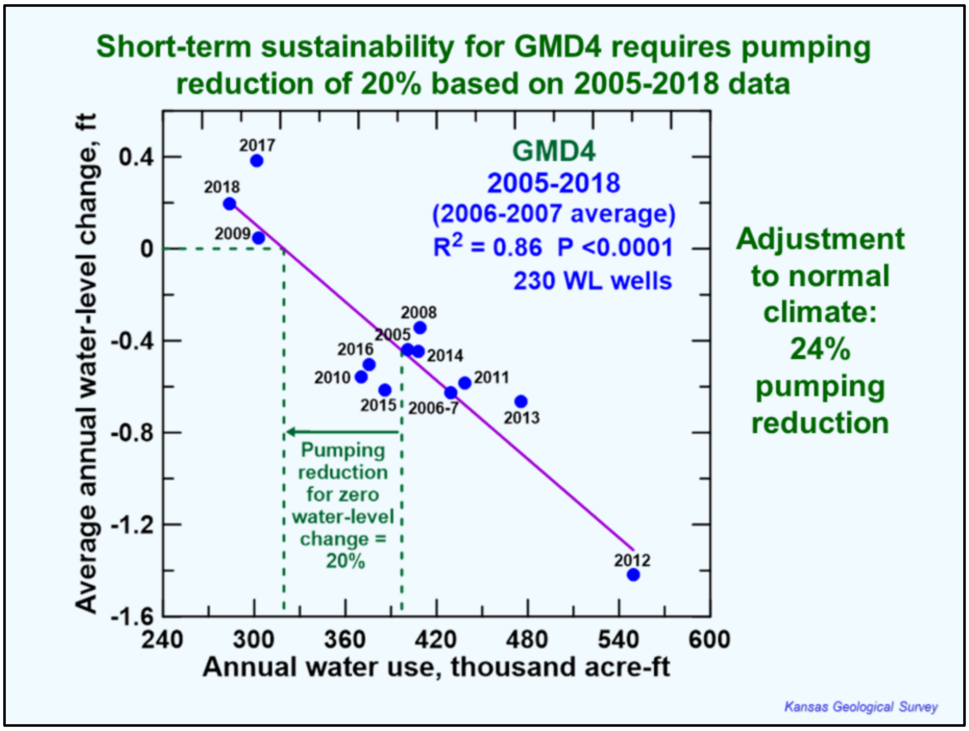
I will now discuss aspects of the Ogallala region of the High Plains aquifer in more detail. Note again that GMD4 is located in the northwest, GMD1 in the west-central, and GMD3 in the southwest part of the state.



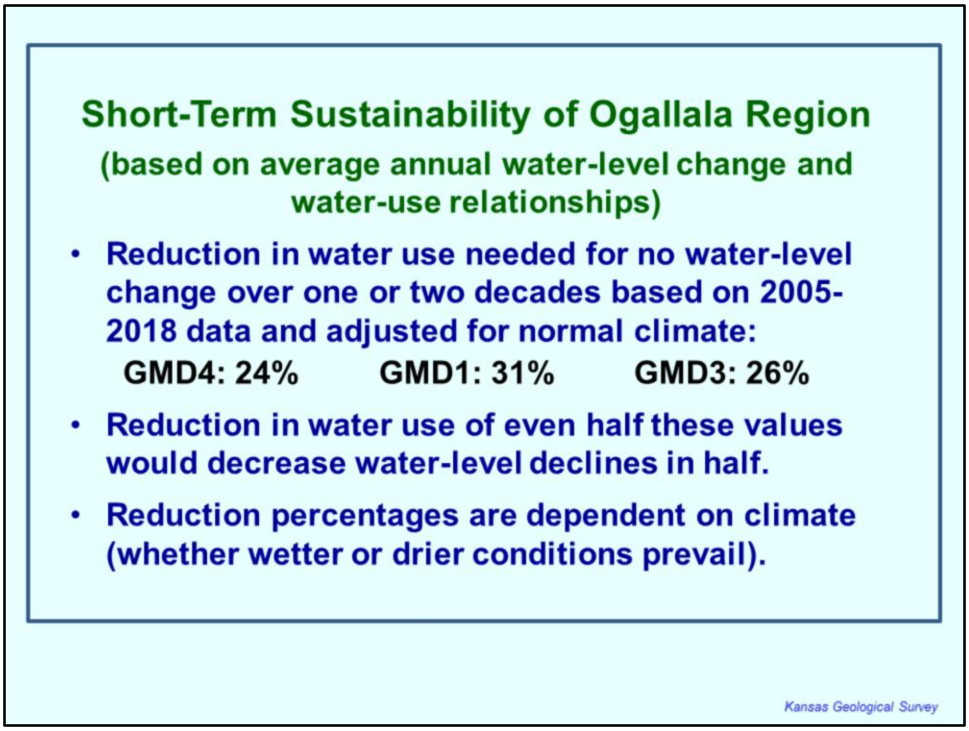
The left-hand set of graphs shows the cumulative average annual decline in groundwater levels in the Ogallala region during 1996 to 2019. The area of GMD3 has experienced the greatest decline, an average of 120 feet since before substantial irrigation development in the 1940s and 1950s, in comparison with cumulative declines of 26 feet and 57 feet in GMDs 4 and 1, respectively. The average remaining aquifer thicknesses are 68 ft in GMD4, 30 ft in GMD1, and 134 ft in GMD3. The right-hand set of plots displays the average annual water-level changes from 1996 to 2019. Values below the horizontal black line indicate declines and values above represent rises. Nearly all of the years have had declines. The average annual water-level changes for the period are declines of 0.46 ft in GMD4, 0.54 ft in GMD1, and 1.7 ft in GMD3.



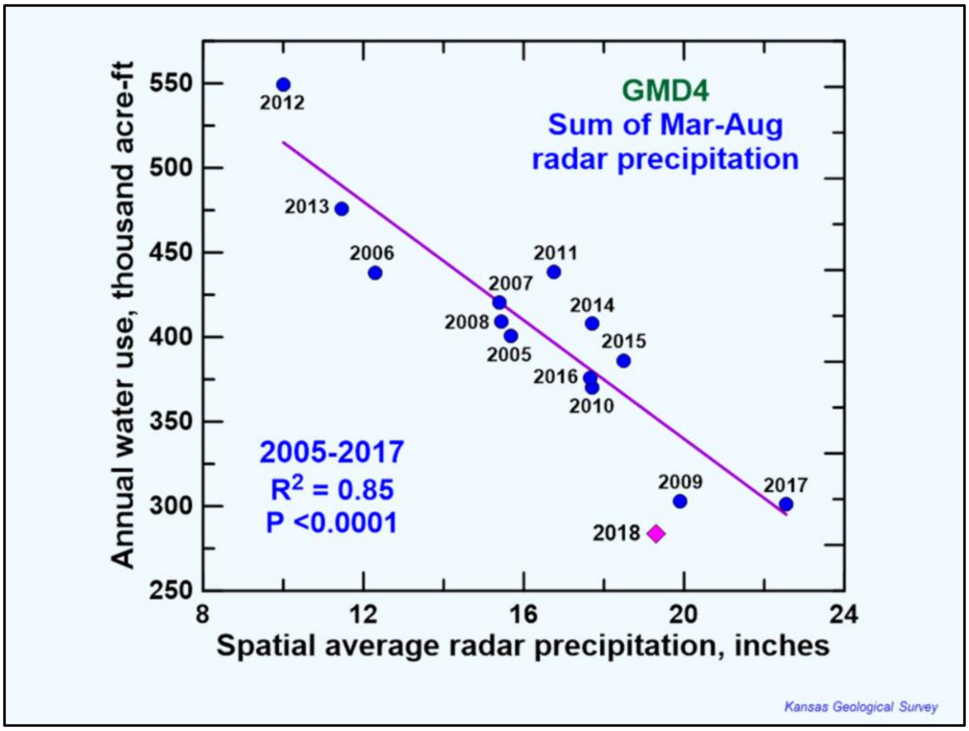
These graphs display the annual water use in the three western GMDs from 1996 to 2018. The trend lines indicate a 14% decrease in GMD4, a 43% decrease in GMD1, and a 17% decrease in GMD3. Most of the water use decrease is expected to be related to the decrease in saturated thickness of the aquifer, although, as I will show for GMD4, recent decreases have occurred as a result of conservation management.



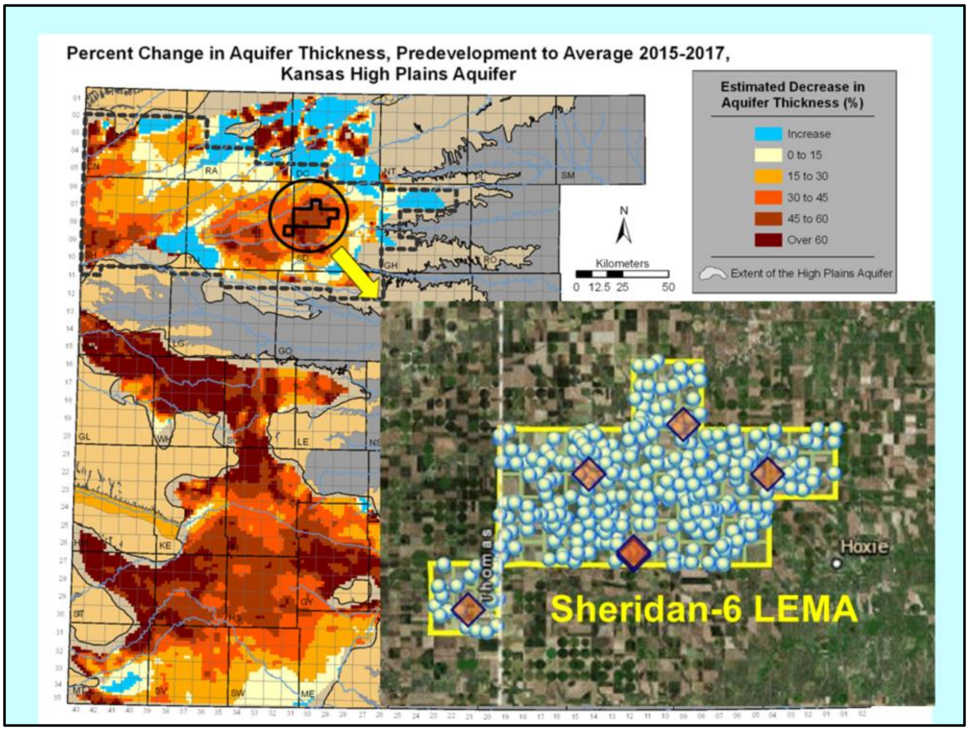
During the last several years, the KGS has developed a water balance approach for estimating the pumping reduction needed for short-term sustainability in the aquifer. This graph is an example for GMD4. Average annual water-level change is plotted versus annual water use, the blue points, and a linear regression is fitted to the data, the purple line. This allows an estimate of the water use at a water-level change of zero, the horizontal and vertical dashed lines that intersect the linear regression. The average reported water use for the period of data, 2005 to 2018, is represented by this vertical dashed line. The water use reduction is the difference between the two vertical dashed lines, 20% for these data. Overall, the period of 2005 to 2018 has been wetter than normal. If an adjustment to normal climate conditions is made, the pumping reduction needed would be 24%.



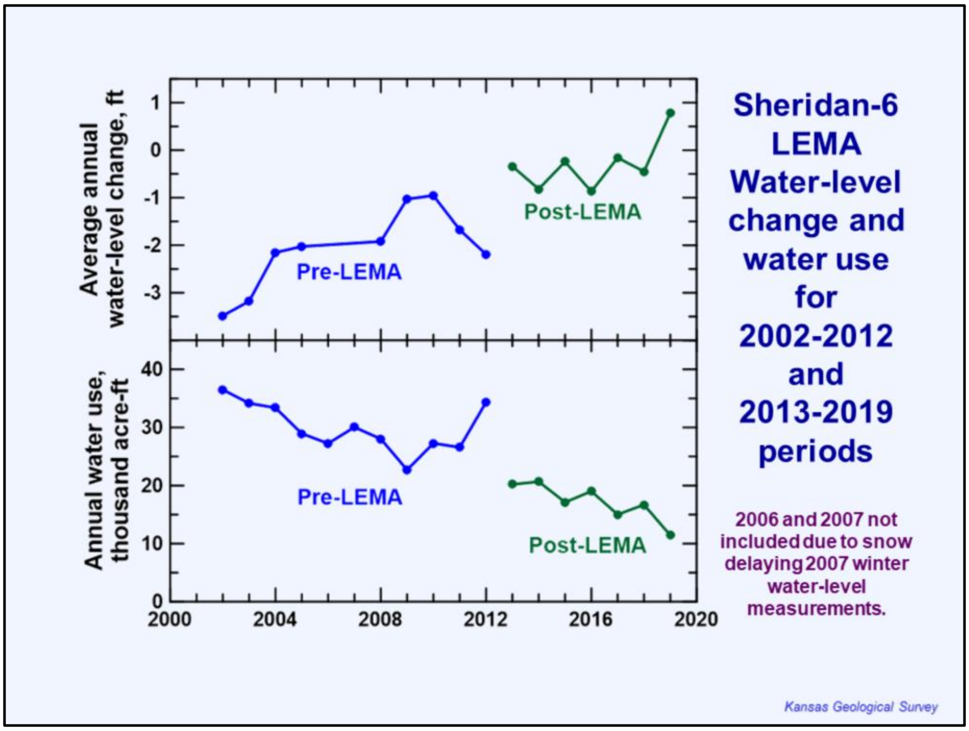
If the water balance approach is used to estimate the pumping reduction for the short-term sustainability for the other two GMDs in the Ogallala region, and then these reductions are adjusted for normal climate, the values are 31% for GMD1 and 26% for GMD3 compared to 24% for GMD4 for 2005 to 2018 data. Reductions in water use of even half of these values, which would certainly be practical, would decrease water-level declines in half. Future climate change will affect pumping reductions for sustainability.



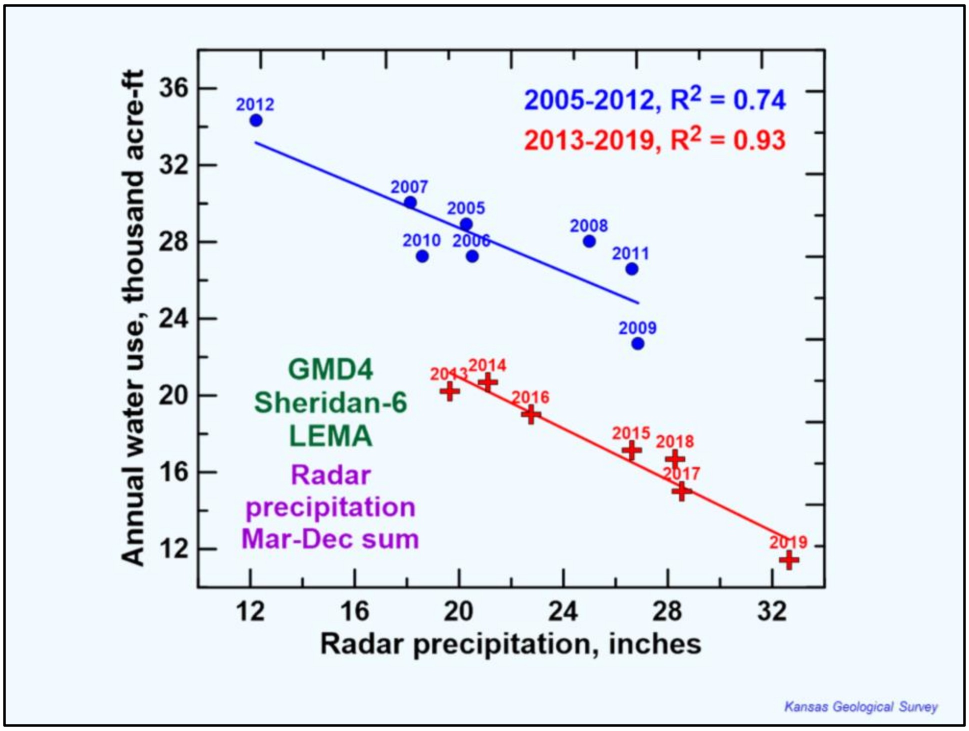
Irrigation pumping from the aquifer is mainly related to the amount of precipitation, as indicated by this graph of annual water use versus spatial average radar precipitation for the growing season in GMD4. The correlation of water use and precipitation is statistically highly significant for the period 2005 to 2017. The point for 2018 lies below the linear regression, the purple line, indicating that the water use was lower than expected for the growing season precipitation. Does this indicate that GMD4 is now conserving water?



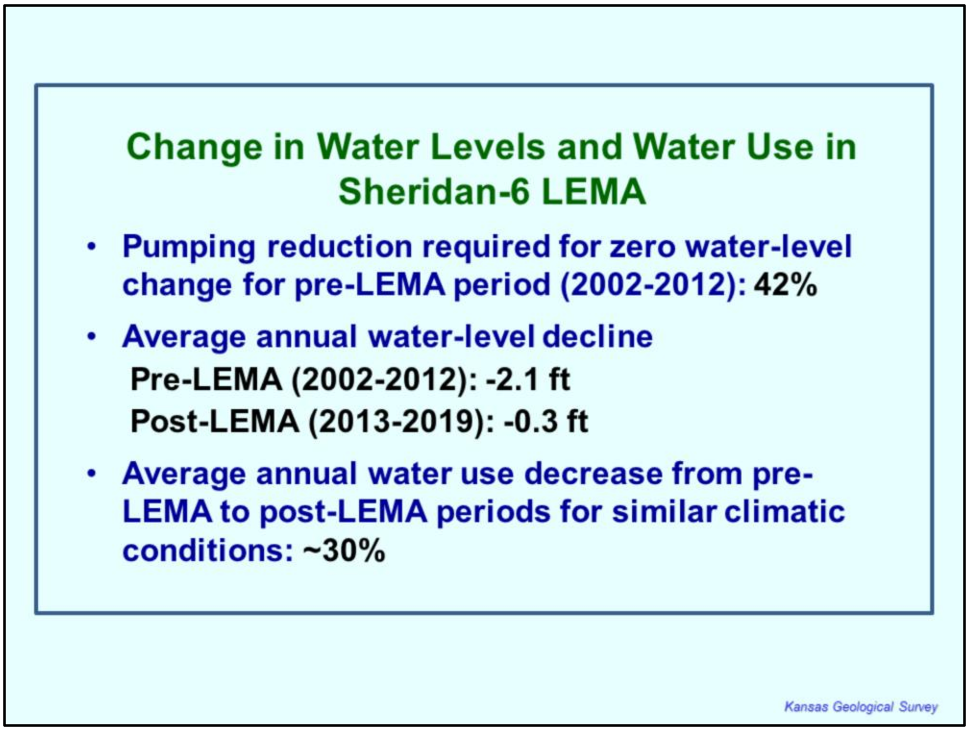
The Kansas legislature passed a law in 2012 that granted the authority for GMDs to initiate local enhanced management areas, known as LEMAs, for water conservation. The first LEMA was established in GMD4 in Sheridan County with a small part in Thomas County. The LEMA is represented by the black outline on the map of aquifer thickness change where water-level declines have been substantial. The enlarged image shows the distribution of irrigation wells within the LEMA. The diamonds are water-level monitoring wells.



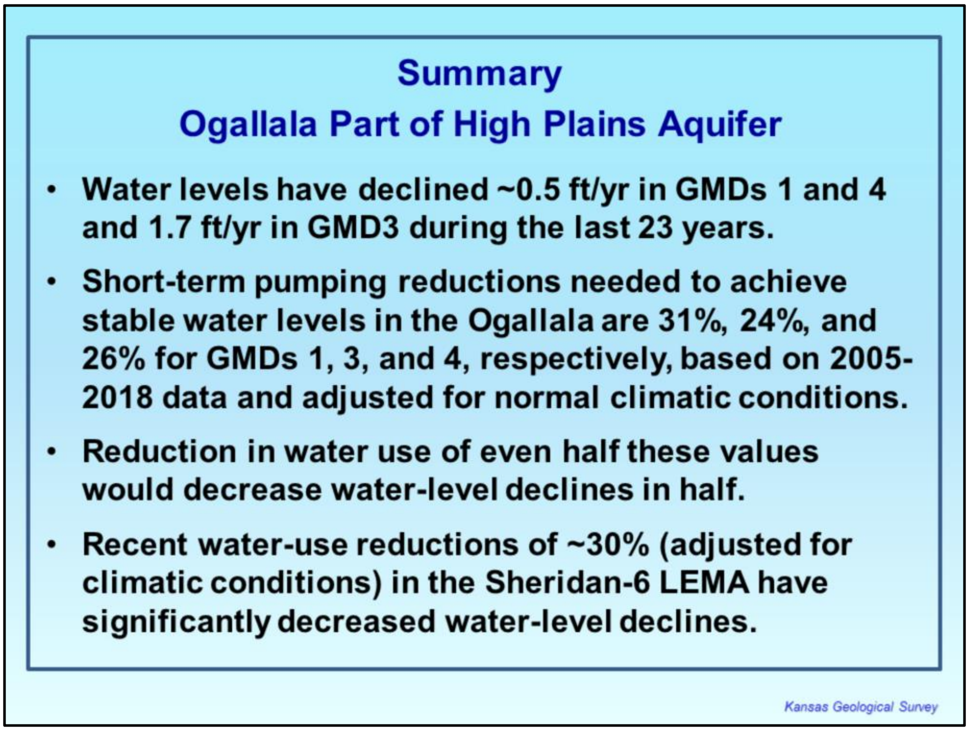
These plots display the average annual water-level change and the annual water use for 2002 to 2019 for the area of the Sheridan-6 LEMA. The blue points indicate the water-level change and water use before the LEMA and the green points the values during the LEMA operation. It is clear that the water-level declines and the water use were substantially less during the LEMA than before.



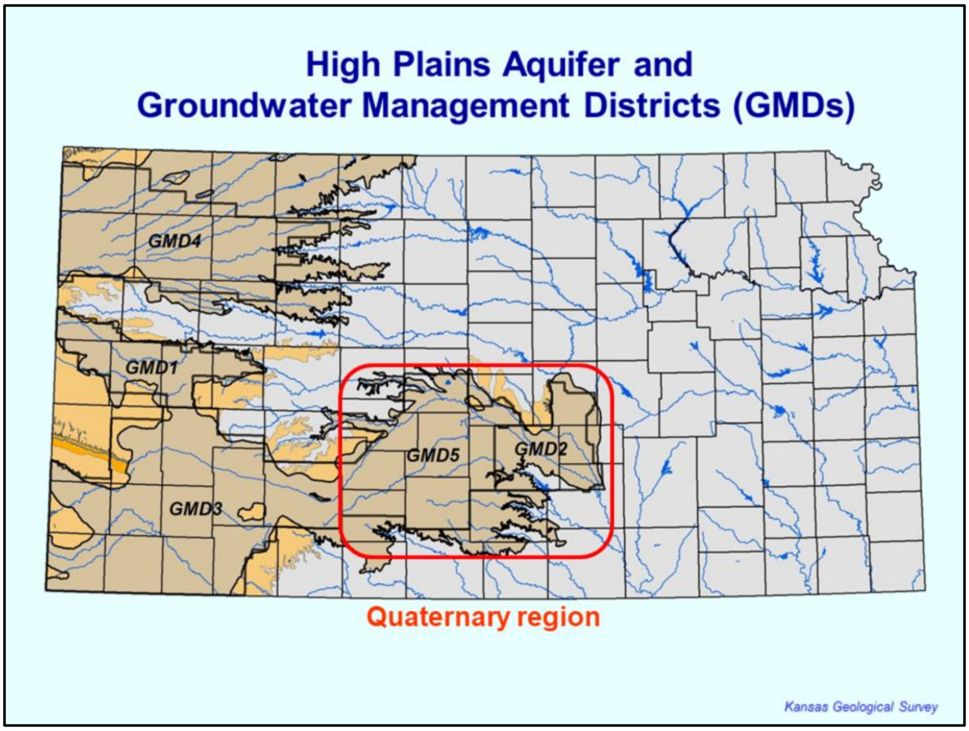
A graph of annual water use versus radar precipitation for the LEMA shows the water conservation. The blue points and linear regression represent the pre-LEMA period, the red pluses and linear regression the period of LEMA operation. The difference in water use at a particular precipitation value indicates the amount of water savings for a particular climate condition.



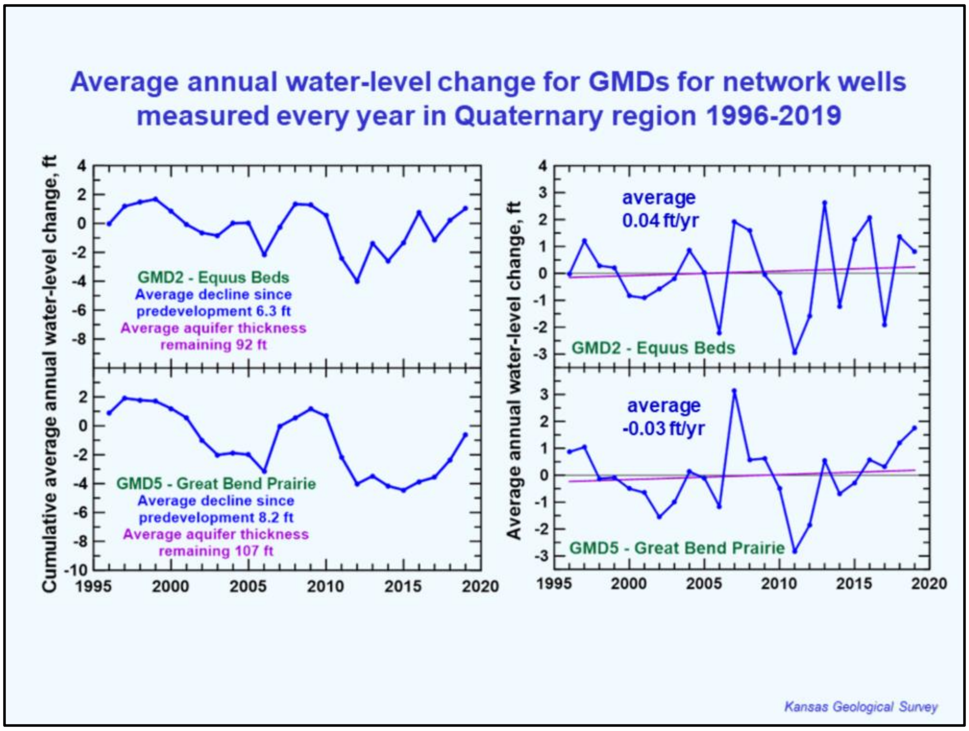
The pumping reduction needed for zero-water level change for the pre-LEMA period was 42%. The average annual water-level declines changed from 2.1 feet during the pre-LEMA period to 0.3 feet after the LEMA establishment. The average annual decrease in water use has been about 30%, which is more than the 20% target of the LEMA for five years. A KSU study reported that there has been no significant decrease in net profits for crop production in the LEMA. The water savings were mainly achieved by better application of irrigation water based on soil moisture sensors and planting of a different mixture of crops.



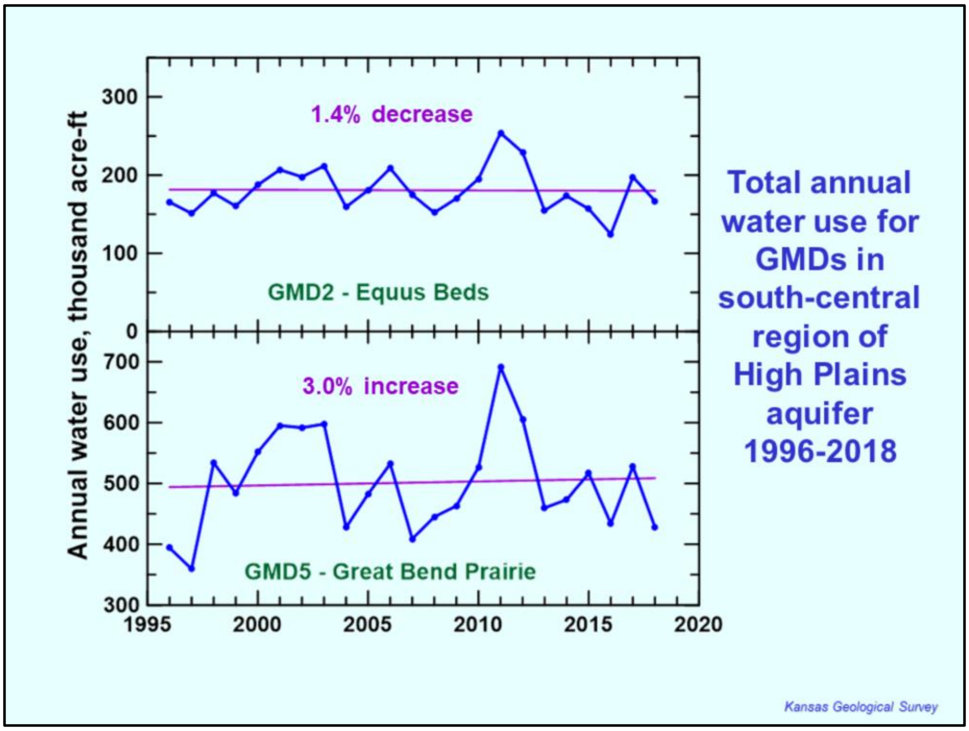
In summary, water levels have declined about a half foot per year in GMDs 1 and 4 and 1.7 foot per year for GMD3 during the last 23 years. Pumping reductions needed for stable water levels and adjusted for normal climate range from 24 to 31 percent for the three GMDs in the Ogallala region. Reductions in water use that are practical and that would not significantly affect crop production would substantially decrease water-level decline rates. The establishment of the Sheridan-6 LEMA has significantly decreased water-level declines. A district-wide LEMA was initiated in GMD4 in 2018 and is expected to result in regional decreases in water-level decline rates.



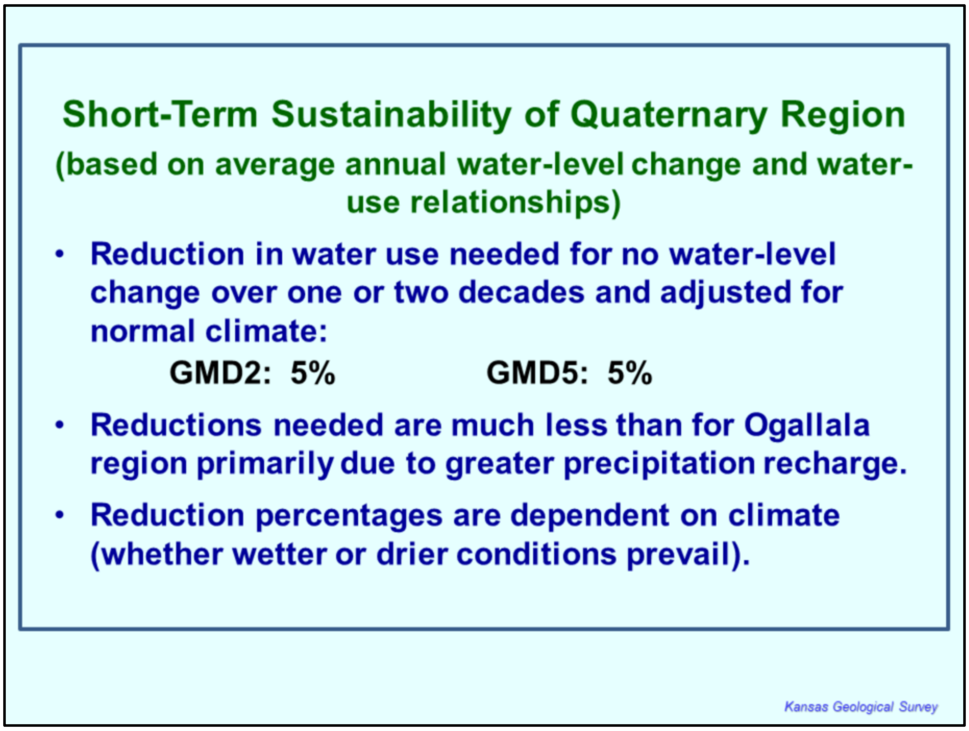
I will now discuss aspects of the Quaternary region of the High Plains aquifer. Note that this region includes GMDs 2 and 5.



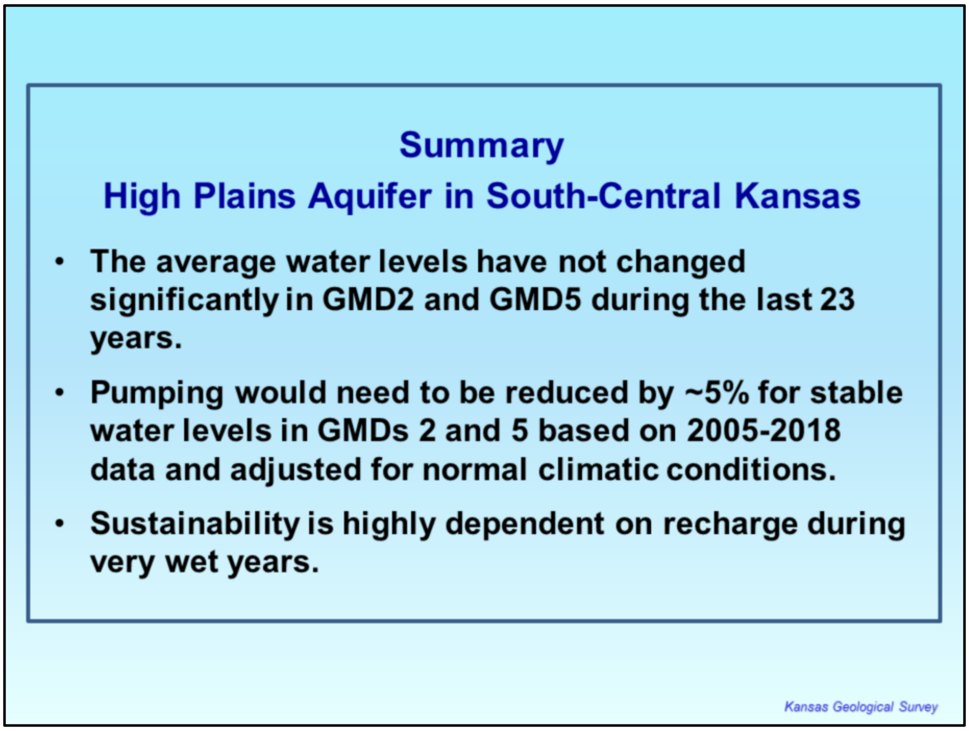
The left-hand set of graphs shows the cumulative average annual decline in groundwater levels in the Quaternary region for 1996 to 2019. The cumulative values range above and below zero and end in 2019 slightly above zero for GMD2 and slightly below for GMD5. The average declines since predevelopment are about 6 feet for GMD2 and 8 feet for GMD5. The current average aquifer thicknesses are 92 ft in GMD2 and 107 ft in GMD5. The right-hand set of plots displays the average annual water-level changes from 1996 to 2019. The values vary substantially from rises and declines as much as three feet. The substantial rises that occur during very wet years are especially important in recharging the aquifer and reversing water-level declines. The average water-level changes for 1996 to 2019 are close to zero for both districts.



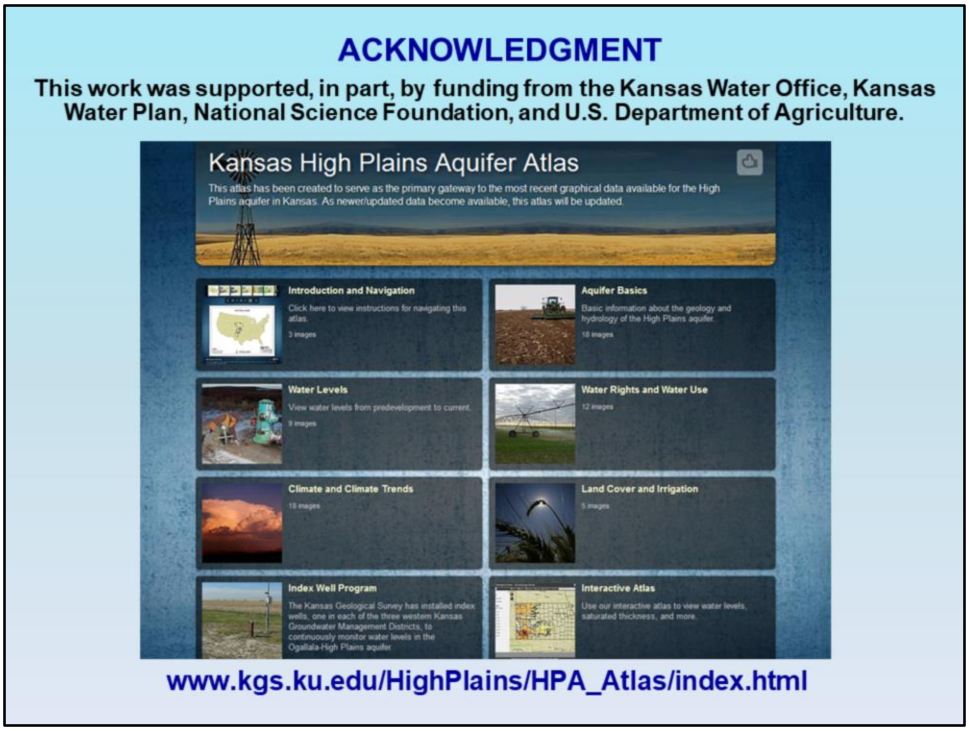
These graphs display the annual water use in GMDs 2 and 5 from 1996 to 2018. The trend lines indicate a 1.4% decrease in GMD2 and a 3% increase in GMD5.



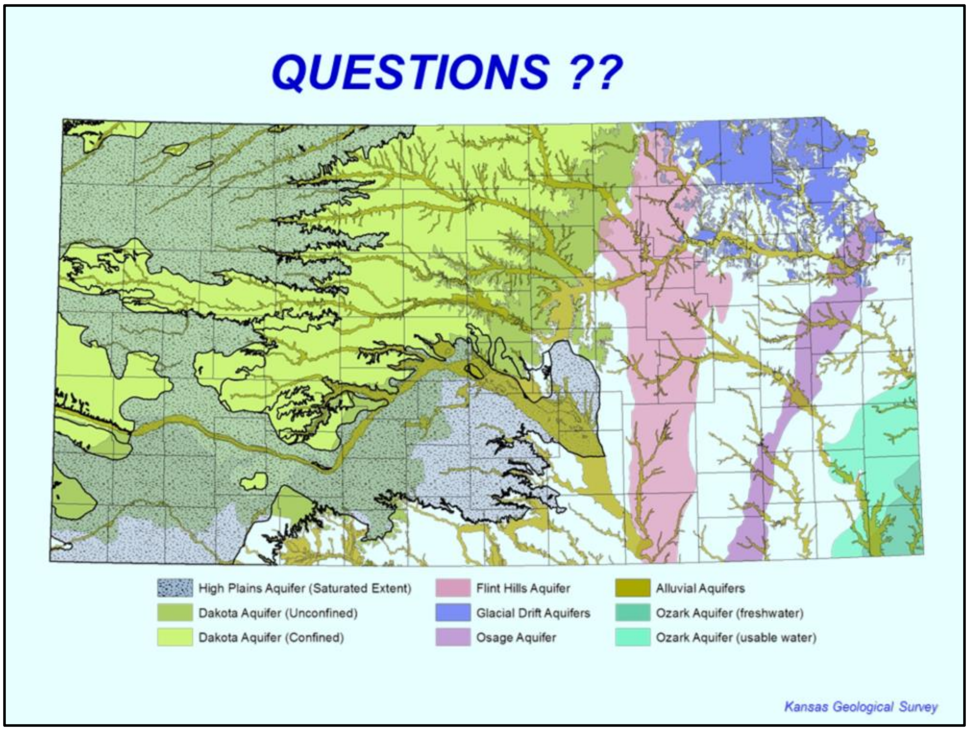
Based on the water balance approach, the estimated pumping reductions for short-term sustainability for both GMDs 2 and 5 are 5% after adjustment for normal climate. The reductions are much smaller than needed for the Ogallala region primarily due to the greater precipitation recharge in south-central than in western Kansas. Extended wet and dry climatic conditions can cause substantial changes in the reduction percentages.



In summary, average water levels have not changed significantly in GMDs 2 and 5 during the last 23 years. However, pumping reductions needed for stable water levels and adjusted for normal climate are about 5% for both GMDs in the Quaternary region based on 2005 to 2018 data. The reason for the estimated reductions is that the period has generally been wetter than normal. The sustainability of the aquifer in this region is highly dependent on recharge during very wet years.



I hope you have found this overview of aquifers in Kansas useful. We acknowledge funding from the Kansas Water Office, the Kansas Water Plan, and the U.S. Department of Agriculture. To find out more about the High Plains aquifer, visit the High Plains aquifer atlas online on the KGS web pages; the link to the atlas is provided here.



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